Spatio-Temporal Changes in Vegetation Greenness Across Continental Ecuador, 1982 - 2010

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Abstract

We analyze changes in vegetation greenness across the coastal, Andean, and Amazonian regions of continental Ecuador, 1982-2010. Using Normalized Difference Vegetation Index (NDVI) anomalies derived from the Advanced Very High-Resolution Radiometer (AVHRR) on monthly and annual bases, we identify: i) long-term changes in annual NDVI, ii) seasonal shifts in greenness patterns, and iii) spatial patterns of change in vegetation greenness. Results indicate overall significant greening, or NDVI increase, after the mid-1990s, with distinct seasonal and regional variations. In the Amazon changes occur between September and February, resulting in a prolonged growing season during the later period. Significant increases are witnessed in coastal regions between February and May, but with no change in growing season. Fluctuations in NDVI in the Andes mimic the coast in the western slopes and the Amazon in the eastern slopes but exclude major changes in NDVI. The research investigates the possible effects of precipitation and CO2, and contributes to the understanding of tropical vegetation change in a rapidly changing environment.

Spatiotemporal Changes in Vegetation Greenness Across Continental Ecuador, 1982 - 2010

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Motivation & Objectives

Tropical vegetation is greening in response to increased atmospheric CO_2, changes in precipitation patterns, and increased insolation [1,2]. However, details of the seasonality of these patterns in the western Amazon and of the magnitude of these changes in equatorial Andean and Pacific areas remains poorly understood. Here, we use the country of Ecuador as a case study to explore:

Research question:
How do the spatiotemporal patterns of vegetation greening vary across an equatorial Pacific-Andes-Amazon gradient from 1982 to 2010?

Data

We utilized the Global Inventory Modeling and Mapping Studies (GIMMS) Normalized Difference Vegetation Index (NDVI) generated from the Advanced Very High-Resolution Radiometer (AVHRR) at annual and monthly bases [3]. Monthly NDVI data were further averaged in triads that span three consecutive months for each of the 12 months of the year.
To facilitate identification of seasonal variations in greening, we calculated standardized seasonal NDVI anomalies using z-score transformations:

$$Z_{tj} = \frac{x_{tj} - \bar{x}_j}{s_j}$$

where, $\bar{x}_j$ and s_j denote means and standard deviations for triad or year *j* for observation *t*

Defining Regions

To identify meaningful regions in terms of NDVI seasonality, we 1) averaged NDVI for each triad over the entire time series, 2) sampled a subset of pixels evenly distributed across Ecuador, and 3) grouped sampled NDVI data using a cluster analysis. Our results highlight four regions with distinct seasonal patterns of NDVI (Figure 1).

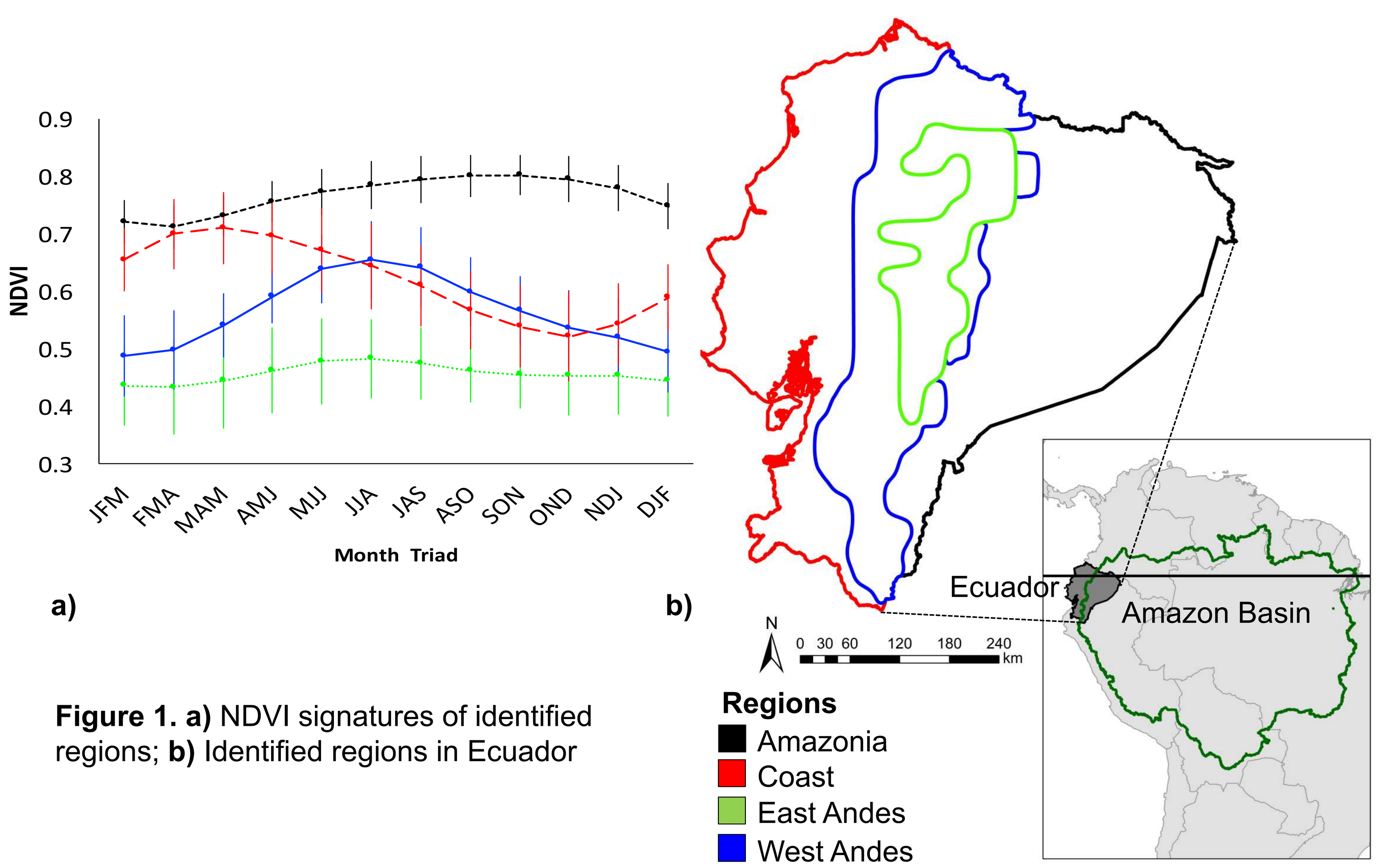

Figure 1. a) NDVI signatures of identified regions; **b)** Identified regions in Ecuador

Long-term Vegetation Greening

In each of the four identified regions, we used yearly NDVI anomalies and a break-point analysis (Pettitt's test) to identify changes in NDVI across the 1982 – 2010 study period. We found that all regions experienced significant breaks in NDVI anomaly around the mid '90s (Figure 2).

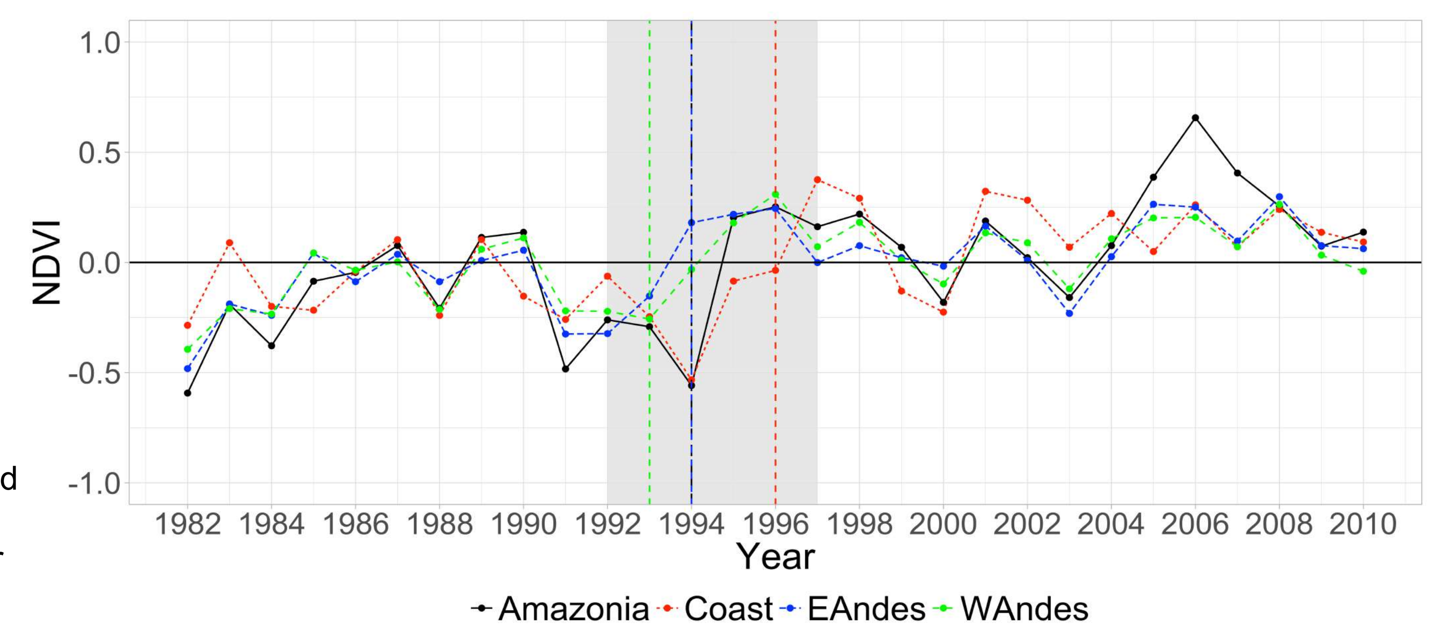

Figure 2. Break point analysis of NDVI anomalies, 1982-2010. Vertical dashed lines denote break point for each region.

Spatial Patterns of Vegetation Greening

Because all regions exhibited significant breaks in the mid '90s, we separated the data into two periods:

1) **Pre-break**: 1982-1992
2) **Post-break:** 1997-2010

To identify areas of significant greening (or browning), we averaged NDVI anomalies for each period for each triad and calculated differences between period means for each pixel. We test the following hypotheses:

Ho: The difference in NDVI anomalies between periods is not significantly different from zero, indicating no significant change in NDVI.

Ha: The difference in NDVI anomalies between periods is significantly different from zero, indicating significant greening or browning.

Results show distinct regional and seasonal variations of greening and browning (Figure 3).

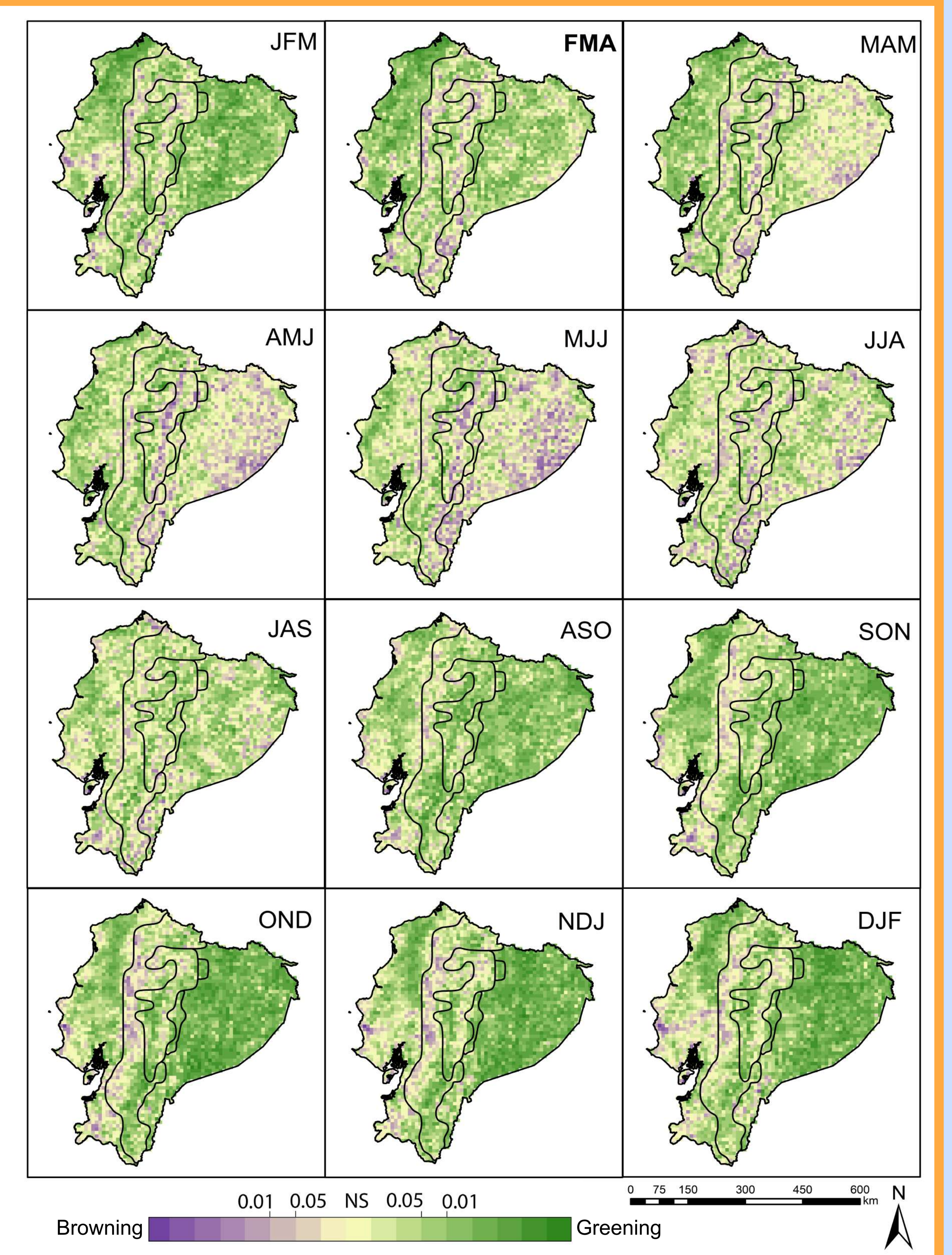

Figure 3. Spatial patterns of vegetation greening and browning for each triad in the four identified regions of Ecuador.

Seasonal Greening Shifts

To examine the magnitude of seasonal changes in NDVI, we performed linear regressions of NDVI anomalies for each triad within each region against year.

Results indicate that Amazonia experienced significant greening between the months of September and February.
Lower greening was detected in the Coast region, but still significant changes occurred between February and May.
Some changes are apparent in the East Andes in January, February, and May while no significant changes were detected in the West Andes (Figure 4).

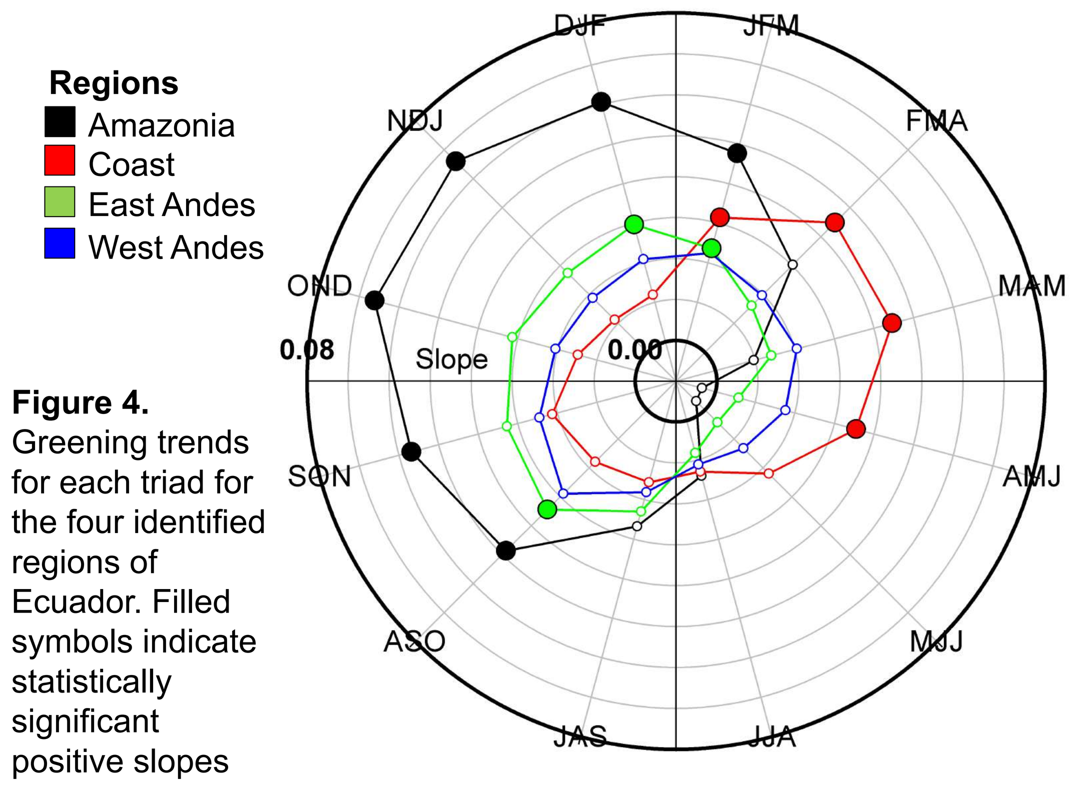

Figure 4. Greening trends for each triad for the four identified regions of Ecuador. Filled symbols indicate statistically significant positive slopes

Lessons and Conclusions

Vegetation in Ecuador greened during the 1982 – 2010 study period. Amazonia exhibits the most pronounced greening trend or lengthening of the growing season, followed by the Coast region. Fluctuations in NDVI in the Andes mimic the Coast in the western slopes and Amazonia in the eastern slopes but exclude major changes in NDVI.

This research contributes to the understanding the response of tropical vegetation to a rapidly changing environment.

Next steps

- Given the precipitation and vegetation gradient of the Pacific coast of South America, expanding the geographic focus of this research to neighboring Colombia and Peru, would contribute to increasing our understanding of vegetation change in coastal and Andean regions.
- To improve the spatial details of our findings, future research should include sensors of finer spatial resolution such as MODIS.
- To assess if greening trends persist or if they are stabilizing, future research should expand the time series.

References

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